Review of calculations for WBLE and DUSEL based water Cherenkov

FNAL-BNL study group meeting
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Outline

- List of issues for water Cherenkov detector at DUSEL.
- Review various calculations so far and how they affect the considerations for the detector.
- Resources used.
  - http://nwg.phy.bnl.gov/~diwan/nwg/fnal-bnl
  - Background rejection study, Yanagisawa, et al.
  - 300 kT detector at Homestake hep-ex/0608023
  - UNO whitepaper, SBHEP01-3, June 2001
    http://ale.physics.sunysb.edu/nngroup/pub/uno_whitepaper.ps
  - SuperK, SNO, and IBM-3 NIM papers.
  - Physics sensitivity calculation, Barger, et al.
    hep-ph/0607177

physics key items

- Long baseline oscillations. For a wide band beam background rejection and resolution study impacts the PMT granularity, and coverage. For this study assumption is 40%, but will need to be examined for detailed detector design. One strategy is to build just enough detector to perform this physics and take everything else for free.
- Proton decay. UNO and HyperK have made estimates of background and sensitivity. Key issue for us could be coverage needed to get sensitivity to kaon-antinu mode with 6 MeV photon tag. 20% coverage may not be enough. (25% gives 25 p.e. for 5 MeV deposit for electrons)
- Diffuse supernova (>19 MeV) sensitivity requires depth. It may also require a veto counter. This veto counter will reduce fiducial volume. Is it needed at ~5000 ft ? Cosmic rate at 4850 is 0.18 Hz.

Other physics topics

- Sensitivity to solar parameters. hep-ph/0607177 has calculation with wide band beam with current understanding of background rejection. Eric Zimmerman/ Bob Davis are attempting to push this farther by using a narrow band off axis beam from FNAL to DUSEL.

- Tau detection. Current method for keeping tau rate low is by keeping the spectrum below 4 GeV using low proton energy. But this affects the average power. How much shaping of the spectrum above 4 GeV can be done while using 120 GeV protons ? Using horn optics and plugs. Can the horn optics be used to sweep the beam edge to make taus at sufficient rate to be seen in a water detector ?

- Could the same detector be used for beta-beam operation in the future ? see talks by Fabich/Rubbia from NUFACT06

Sensitivity calculations

- Will now review calculations from hep-ph/0607177.
- Assumptions
  - 1 MW operation in nu mode for 5 yrs (1.7e7 sec/yr)
  - 2 MW operation for anti-nu mode for 5 yrs(1.7e7sec/yr)
  - WBLE(28 GeV) spectrum. Bishai has shown same for WBLE(40 GeV). Work needed on WBLE(120GeV)
  - 300 kT fiducial mass
  - Total background ~same as Yanagisawa et al.
  - Input parameters $\theta_{12} = 0.55 \pm 10\%\,, \qquad \Delta m^2_{21} = (8.0 \pm 0.8) \cdot 10^{-5}\,\mathrm{eV}^2\,,$

    $\theta_{23} = \pi/4 \pm 5\%\,, \qquad \Delta m^2_{31} = (2.5 \pm 0.125) \cdot 10^{-3}\,\mathrm{eV}^2\,.$
  - GLoBES calculation with full correlation consideration.

Background

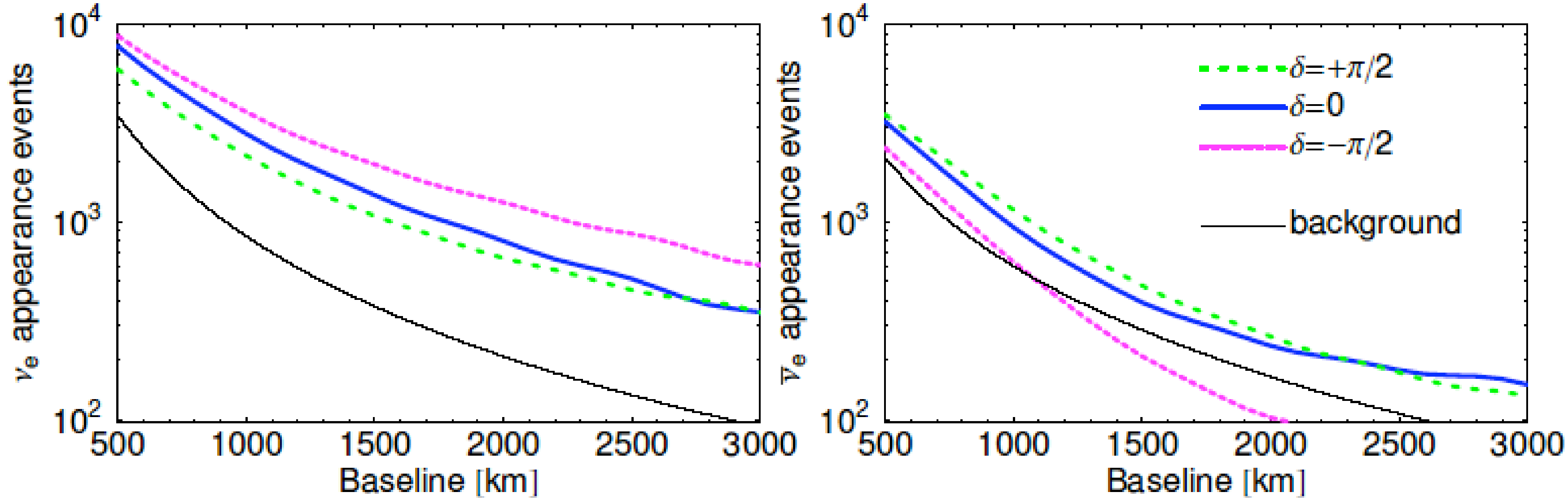

Figure 1: Event rates for neutrinos (left-hand panel) and antineutrinos (right-hand panel) as a function of baseline for $\sin^2 2\theta_{13} = 0.1$ and a normal hierarchy. The bold lines show the signal for various choices of δ_{CP}. The thin line shows the total background, which includes background from beam contamination and neutral current events.

Backg@1300: Total backg in calculation adjusted to match Yanagisawa.

Yanagisawa et al.: 492 events(308(nc)+183(nue))

Calculation: 513 events(273(nc)+240(nue))

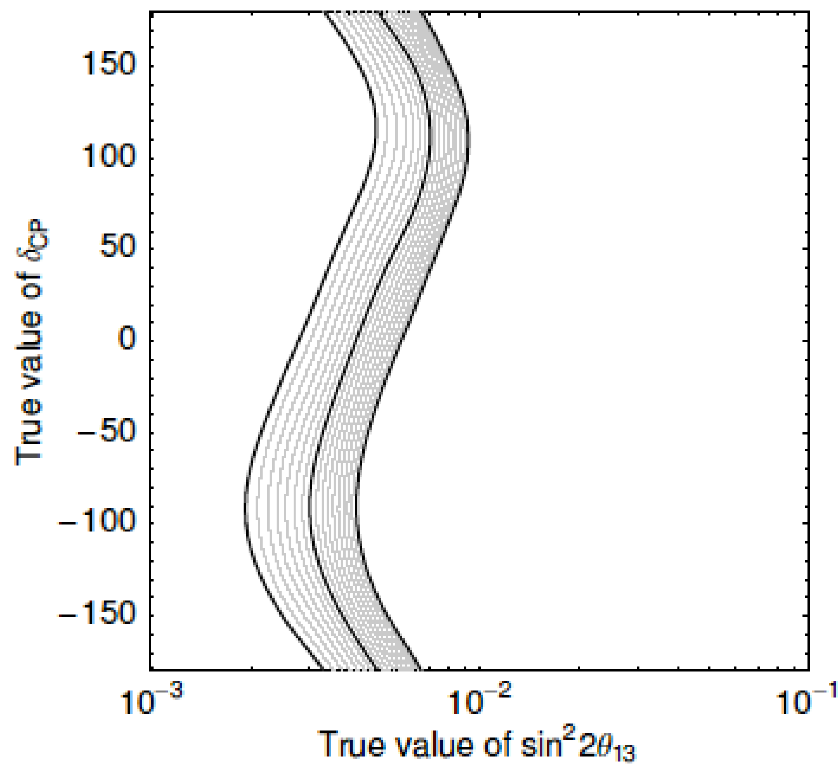

Figure 2: Discovery potential for $\sin^2 2\theta_{13} \neq 0$ at a baseline of 1300 km. The bold iso-χ^2 lines are $3, 4, 5\,\sigma$ (from left to right) and the light lines show an increase of χ^2 by 1. For all points to the right of the rightmost bold line, a nonzero value of $\sin^2 2\theta_{13}$ can be established with at least 5σ significance.

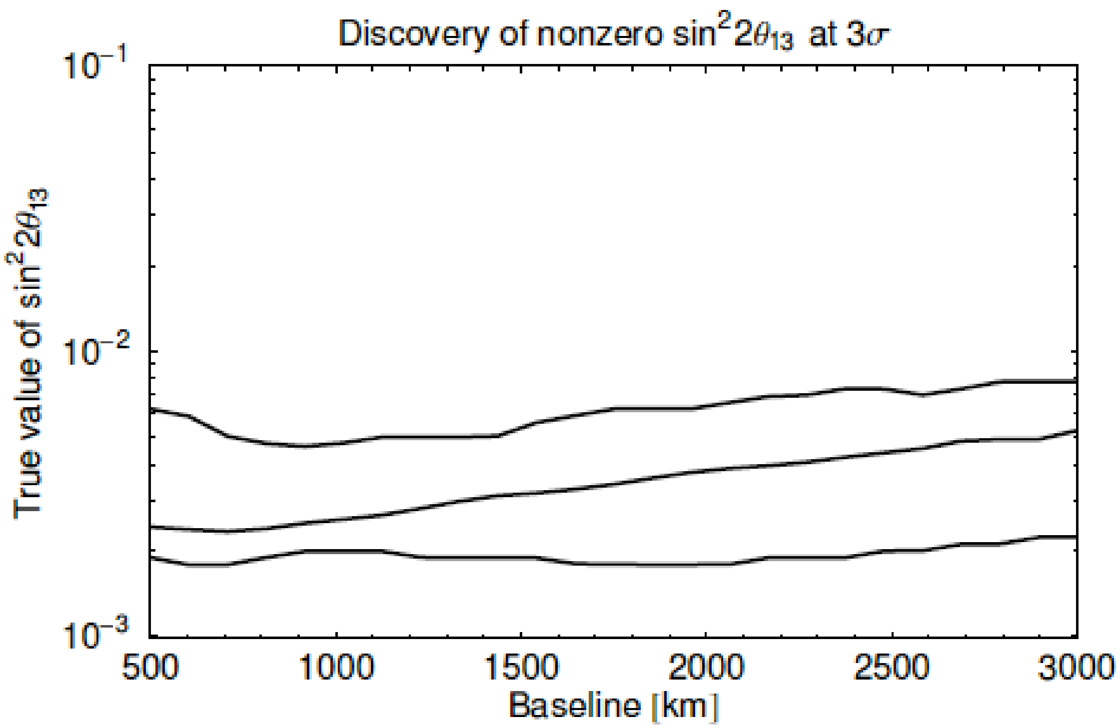

Figure 4: Discovery reach for $\sin^2 2\theta_{13} \neq 0$ at 3σ for CP fractions 0 (lowermost line, best case), 0.5 (middle line) and 1 (uppermost line, worst case) as a function of the baseline. The detector mass, beam power and exposure are kept the same for all baselines.

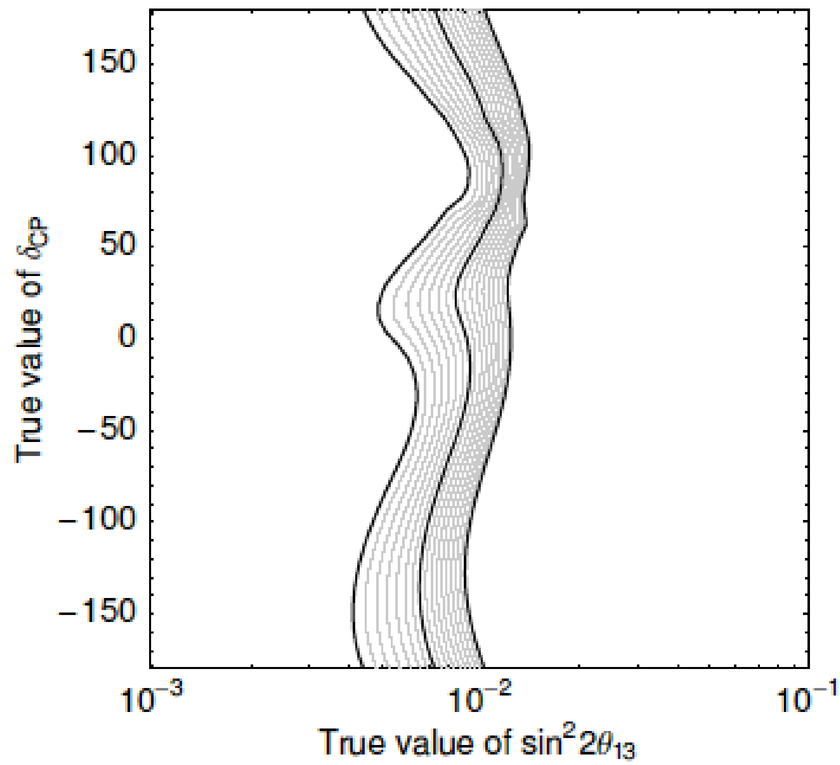

Figure 5: Discovery potential for a normal mass hierarchy at a baseline of 1300 km. The bold iso-χ^2 lines are $3, 4, 5\,\sigma$ (from left to right) and the light lines show an increase of χ^2 by 1. For the inverted hierarchy the results are approximately the same because of the approximately symmetric ν and $\bar{\nu}$ running.

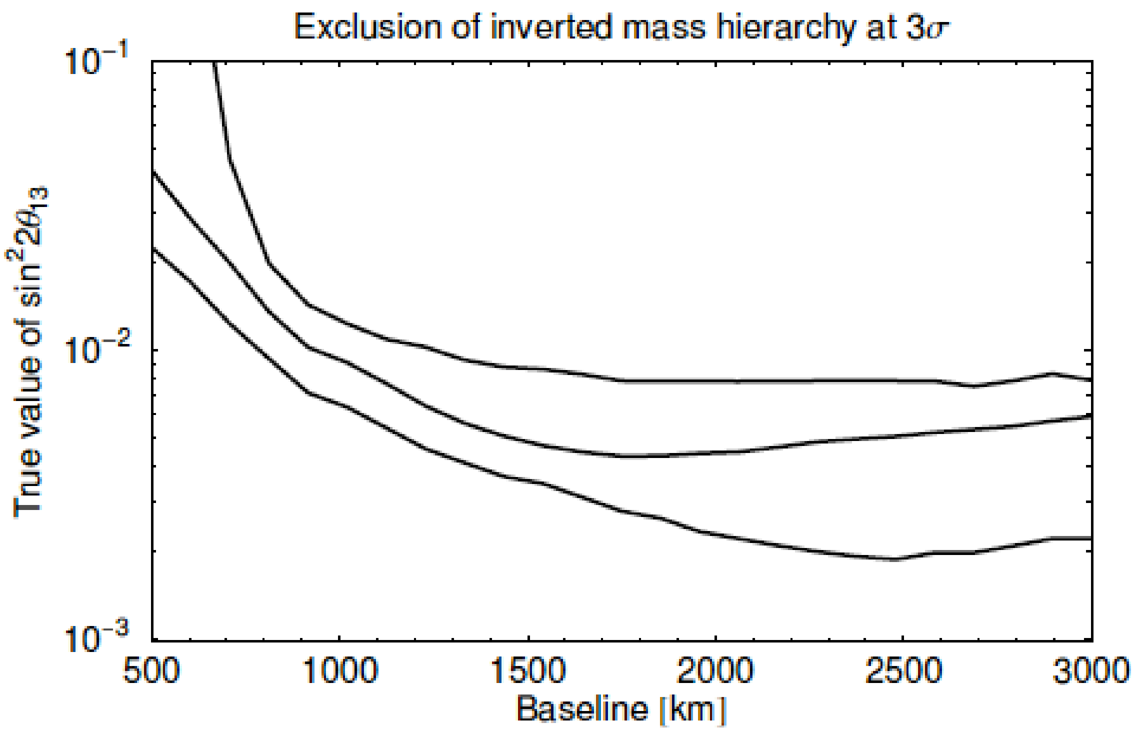

Figure 6: Discovery reach for a normal mass hierarchy at 3σ for CP fractions 0 (lowermost line, best case), 0.5 (middle line) and 1 (uppermost line, worst case) as a function of the baseline. The detector mass, beam power and exposure are kept the same for all baselines.

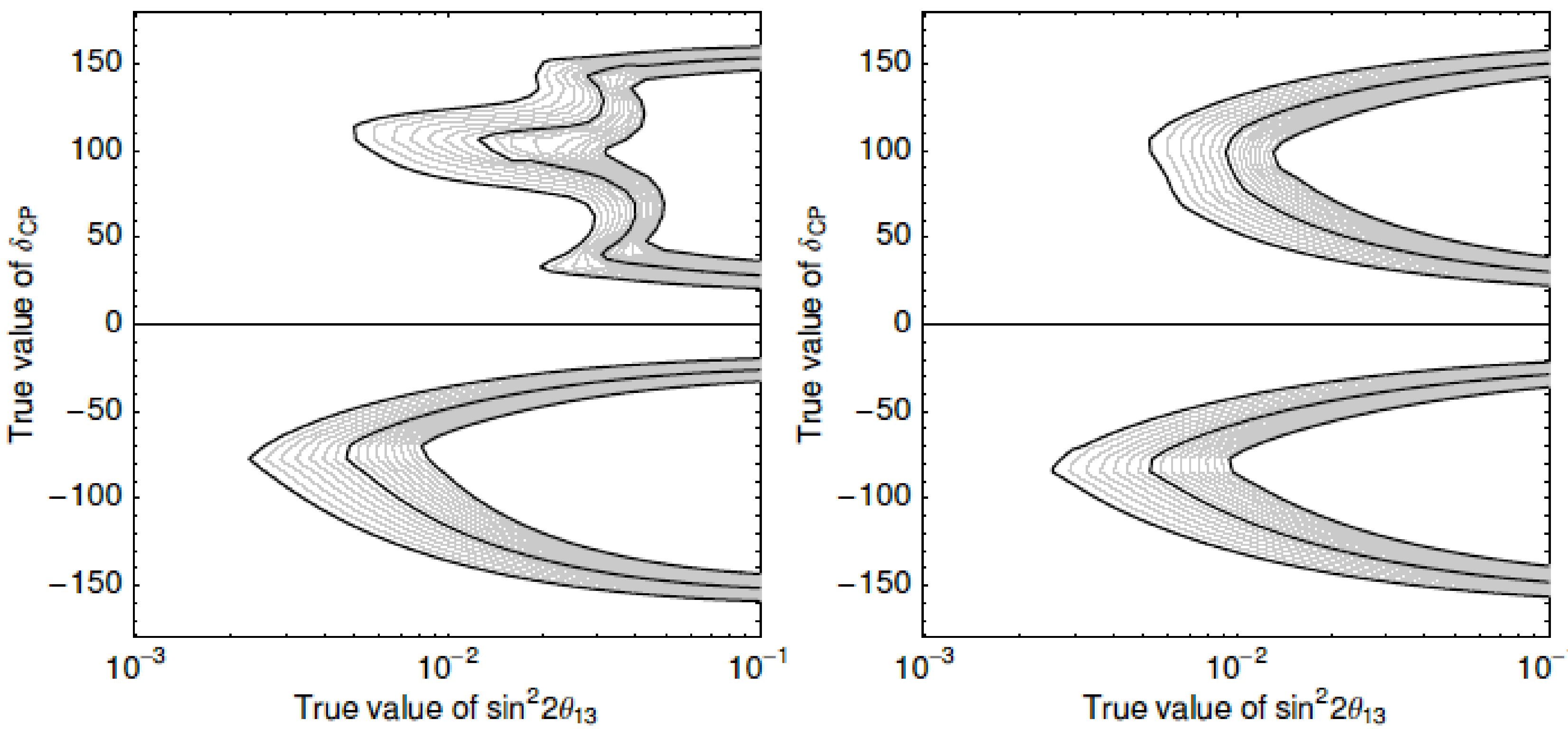

Figure 7: Discovery potential for CP violation at baselines of 730 km (left-hand panel) and 1300 km (right-hand panel). The bold iso-χ^2 lines are $3, 4, 5\,\sigma$ (from left to right) and the light lines show an increase of χ^2 by 1. For all points to the right of the rightmost bold line, CP violation can be established with at least 5σ significance.

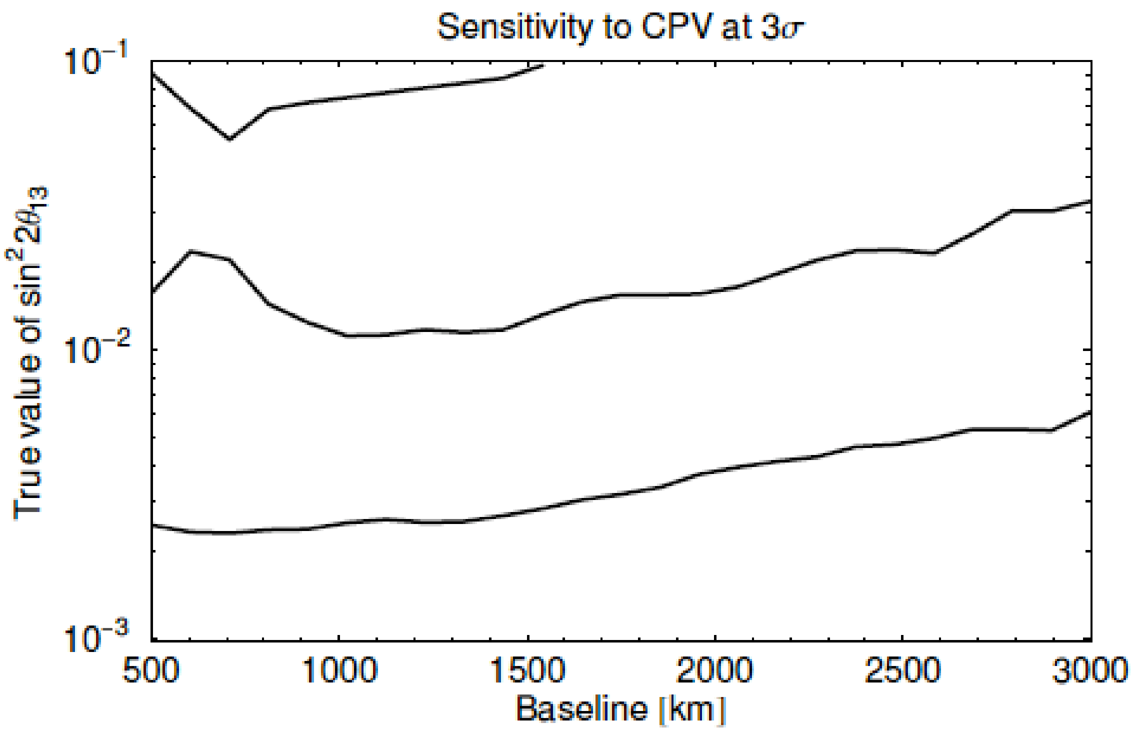

Figure 8: Discovery reach for CP violation at 3σ for CP fractions 0 (lowermost line, best case), 0.5 (middle line) and 0.75 (uppermost line) as a function of the baseline. The detector mass, beam power and exposure are kept the same for all baselines.

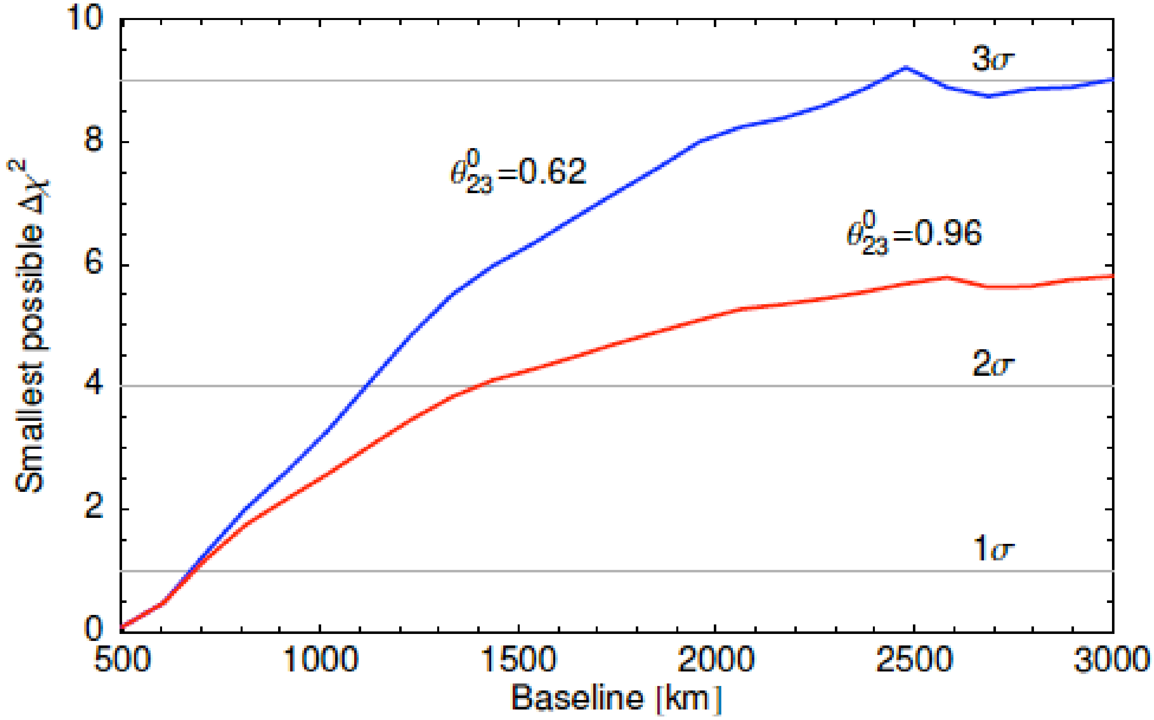

Figure 9: Discovery reach for the octant of θ_{23}. Only the most conservative case with respect to the true values of θ_{13} and $\delta_{\rm CP}$ is considered. The χ^2 difference between the true and wrong octant is shown as a function of the baseline for two representative true values of θ_{23} that are far outside the 1σ range in Eq. (1) (so as to emphasize how challenging this measurement is). The detector mass, beam power and exposure are kept the same for all baselines.

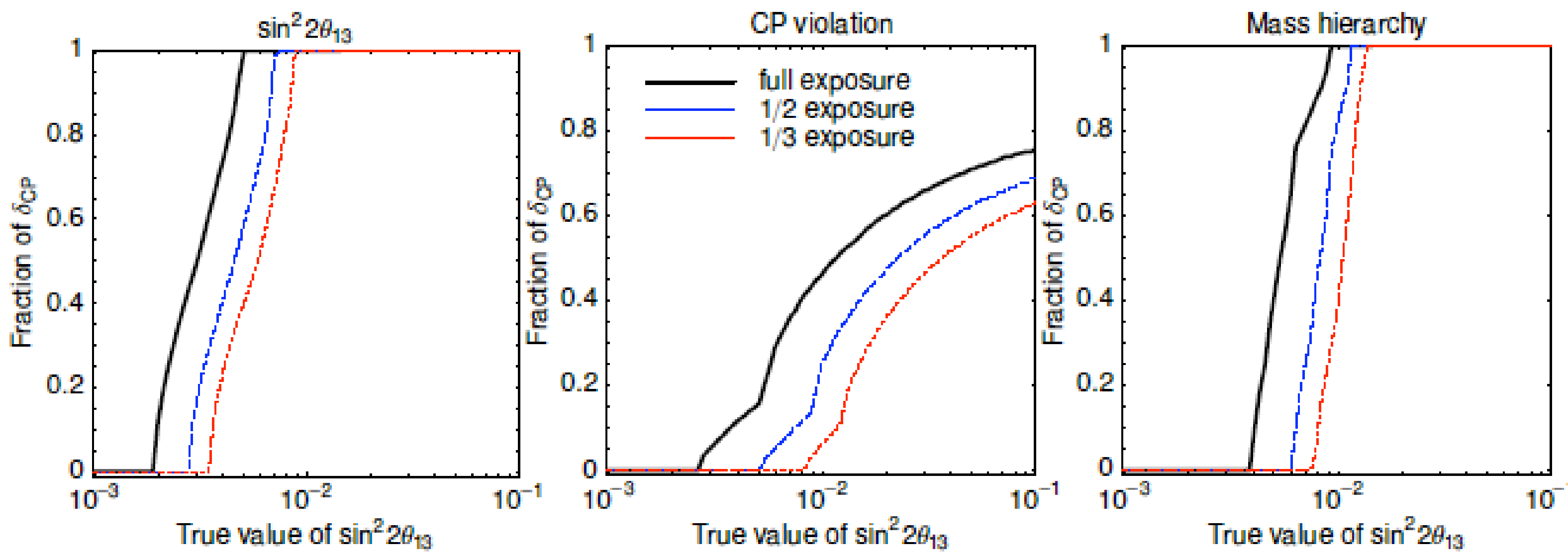

Figure 10: Dependence of the 3σ sensitivities on exposure for an experiment with 1300 km baseline. The two cases considered are 1/2 and 1/3 of the (full) exposure we have used throughout.

This plots says that 2 MW upgrade is not needed immediately for this physics. If the effect is dicovered then or measurement it will add great value.

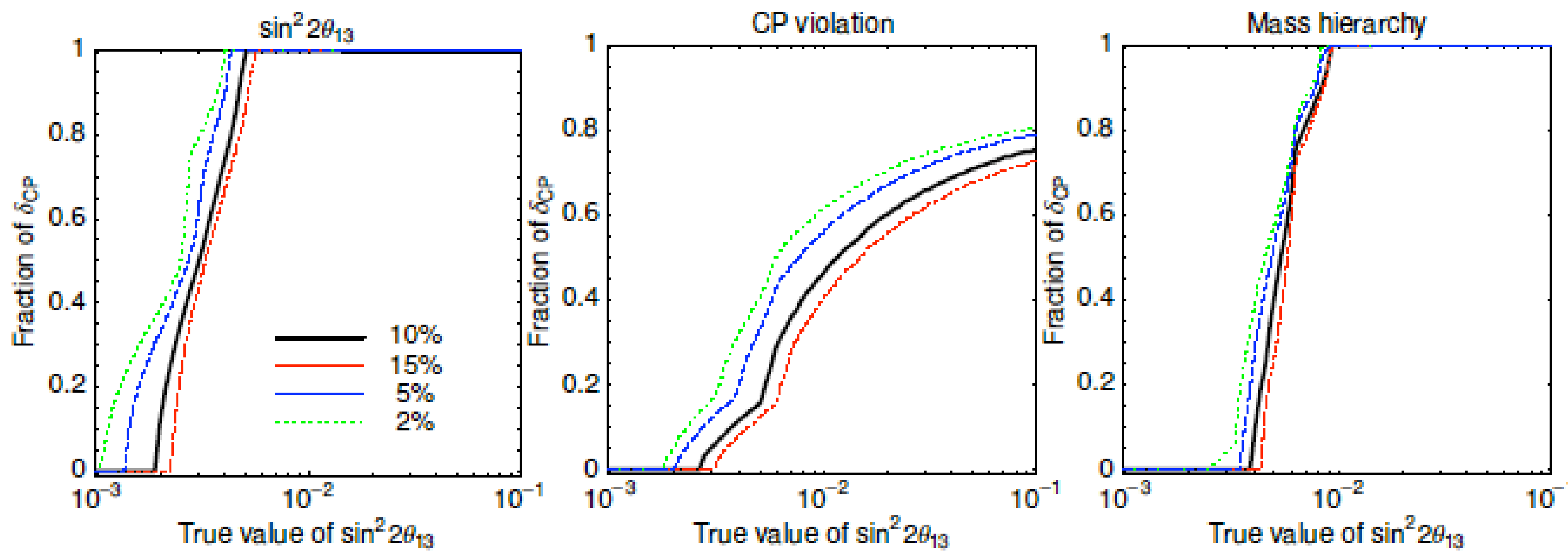

Figure 11: Dependence of the 3σ sensitivities on the uncertainty in the overall normalization of the background for an experiment with a 1300 km baseline. We have adopted a 10% uncertainty throughout.

This plot says that a factor of 2 increase in NC background or poor systematics on the background will not hurt.

Thank You !